Dual-Port Multiband MSA for Airborne Vehicular Applications

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Abstract This paper presents the design of a dual-port microstrip patch antenna for telemetry (2.2 Ghz) and GPS (1.5 Ghz) applications. The proposed antenna is suggested to be used in a low-altitude space rocket or satellite. Any data collected from the rocket would be sent to the base telemetry station through the 2.2 Ghz frequency band. The GPS band would be used to monitor the location of the spacecraft and to collect the information of its trajectory. CST Microwave Design Studio software has been used to simulate the design of the said antenna. The analysis of return loss, VSWR, gain, and radiation pattern was carried out. The proposed antenna shows return loss of −19.23 dB at 2.2 GHz and −20.31 dB at 1.5 GHz (both are orthogonally polarized to each other) which implies good results. The impedance matching is good at the desired frequencies with VSWR <2, respectively. The overall simulation results show that the antenna worked well at the desired two frequencies, hence making the antenna suitable for use. This antenna is implemented on FR4 epoxy dielectric substrate with relative permittivity $\epsilon_r = 4.3$ and thickness of the substrate $(h) = 1.6$ mm.

Keywords Dual-port microstrip patch antenna · Orthogonal polarization
Telemetry · GPS

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1 Introduction

The need to save space on the chipboard of an airborne aircraft has always been paramount. The airborne applications of wireless communication require an antenna to be operated with more than one frequency, and this necessitates a dual-band operation. The design of such antennas for communication application is a tough challenge by itself.

Microstrip patch antennas, with their obvious advantage of low profile, low weight, conformability, and ease of integration, become a suitable choice for airborne applications. In this paper, a dual-band rectangular microstrip patch antenna for telemetry and GPS application is designed and simulated using CST Microwave Studio. The proposed patch antenna resonates at 2.2 GHz (telemetry) and 1.5 GHz (GPS) frequency.

The method employed to feed the proposed antenna is the discrete port excitation technique. This has an advantage that the feed can be placed at any desired position inside the feed line in order to obtain a suitable impedance matching. In the proposed design, two feed points are chosen for the antenna to operate at the two designated frequencies. To minimize interference and obtain good isolation between the two ports, one feed point is centrally fed and the other feed point is edge corner-fed. The centrally fed port attains linear polarization, and the edge corner-fed port attains circular polarization which is orthogonal to one another other resulting in good port isolation.

Polarization diversity has been employed to overcome the limitations of space and has been obtained by colocating the orthogonal polarization on the same patch. Polarization diversity requires less space compared to physically separate antennas [1, 2]. The task at hand is to obtain sufficient isolation between the ports [3] and, at the same time, striving to maintain good matching of impedance and polarization sense [4].

The use of dual-polarized antenna [5–8] for several applications has been extensive. This paper proposes an antenna able to excite two orthogonal polarizations simultaneously. The ports are excited through separate feeds with the radiating structure being the same, and the design does not require any extra dimensions. Compared to [9], a good isolation between the ports is reported.

2 Design Methodology

The characteristics of the microstrip patch antennas are defined mainly by their geometries and the material properties from which they are made of. The designed rectangular microstrip patch antenna has dimensions of 62.42 × 58.38 mm. The FR4 epoxy substrate has been chosen with a dielectric constant ($_r$) of 4.3, dielectric loss tangent of $=0.002$, and a thickness of 1.6 mm. The chosen value of $_r$ gives better efficiency. Besides, it is required that the substrate material be flexible enough for it to wrap around the curved surface of a missile or that of a spacecraft. A much higher value of $_r$ can significantly reduce the antenna's radiation efficiency and also its bandwidth.

The design presented in the paper consists of an active radiating patch on one side of a dielectric substrate and the ground plane on the other. For multiband purpose, two feed points are chosen with orthogonal polarization.

The first step was designing the microstrip patch antenna operating at 2.2 GHz. Once it was achieved, different configurations of the second feed were tried out. After a few trials, Port2 resonated at 1.5 GHz when it was a diagonal corner-fed.

In the above design, two feed points are chosen for the antenna to operate at two frequencies [10]. To achieve minimum interference between the two ports and to attain good port isolation, one feed point is centrally fed and the other feed point is edge-fed [11, 12]. As a result of this, the centrally fed port attains linear polarization and the corner-fed port attains circular polarization. Both these types of polarization are orthogonal to each other, thus attaining a good port isolation.

3 Feeding Techniques

The various feeding techniques can be classified into two main categories, namely contacting and non-contacting. In the former method, power to the radiating patch is fed directly using a connecting line. A microstrip line can be chosen as an example. In the latter non-contacting method, we resort to coupling of the electromagnetic field between the microstrip line and the radiating patch. The techniques being practically employed are the microstrip line and coaxial probe for the direct contact method. For non-contacting techniques, aperture coupling and proximity coupling are employed.

The designed microstrip patch antenna incorporates a microstrip feed line to feed the RF waves to the radiating element. Microstrip feed line is easy to fabricate, and it is also easy to match the impedance of the feed line with the patch by adjusting the inset position. At times when the substrate thickness is large, surface waves and spurious feed radiation increase which results in the loss of bandwidth. But for the above design, microstrip feed line has been found suitable. Here, the conducting microstrip is directly connected to the patch antenna at its edge. The conducting strip has been designed thinner, compared to the patch. The advantage that incurs is that the feed can be etched on the same substrate in conformation to the planar structure.

4 Physical Parameters of Antenna

The different parameters of this antenna have been calculated by the transmission line method [13–18], as reflected in Table 1.

Step 1: Width of the Patch

The width is determined by

Table 1 Parameter list

Serial number	Parameter	Value(mm)
1	Length of patch (L_p)	40.71
2	Width of patch	31.14
3	Length of substrate	62.42
4	Width of substrate	58.38
5	Length of inset feed_1	9.9
6	Length of feed line_1	26.83
7	Length of inset feed_2	6.07
8	Length of feed line_2	22.54
9	Thickness of substrate	1.6
10	Thickness of patch	0.1
11	Thickness of ground	0.1

$$W = \frac{c}{2f_o\sqrt{\left(\frac{\epsilon_r+1}{2}\right)}} \tag{1}$$

where c is velocity of light, f_0, the resonant frequency, and ϵ_r, the relative dielectric constant.

Step 2: Knowing patch width, effective permittivity is determined as:

$$\epsilon_f = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \tag{2}$$

where h is height of the dielectric substrate.

Effective permittivity must be taken into consideration the presence of fringing fields. These are a part of the electric field lines that are partly in the substrate dielectric and partly in the air and are the main contributors to radiation from the patch.

Step 3: Length extension of patch

Due to fringing effects, the electrical length patch of the microstrip antenna looks greater than its physical dimensions. This phenomenon will be represented by ΔL, which is a function of the effective dielectric constant ϵ_f and the width-to-height ratio (W/h) found as:

$$\Delta L = h(0.412)\frac{(\epsilon_r + 0.3)\left(\frac{w}{h} + 0.264\right)}{\left(\epsilon_f - 0.258\right)(h + 0.8)} \tag{3}$$

Step 4: Effective length of the patch

As length of the patch has been extended by ΔL, the effective length is found as:

$$L_f = \frac{c}{2 f_o \sqrt{\epsilon_f}} - 2\Delta L \tag{4}$$

Step 5: Calculation of total characteristic impedance of the microstrip transmission line

$$Z_l = \sqrt{Z_0 Z_{\text{in}}} \tag{5}$$

where antenna is matched to $Z_0 = 50\Omega$

Z_{in} is the input impedance of the patch antenna.

Step 6: Calculation of inset feed length of the microstrip patch antenna

$$R = \frac{L}{\pi} \cos^{-1} \sqrt{\frac{Z_0}{Z_l}} \tag{6}$$

where R is the length of the inset feed.

Step 7: Calculation of length of the microstrip transmission line

$$L_{\text{t}} = \frac{c}{4 f_0 \sqrt{\in_r}} \tag{7}$$

where L_{t} is the length of the transmission line Fig. 1.

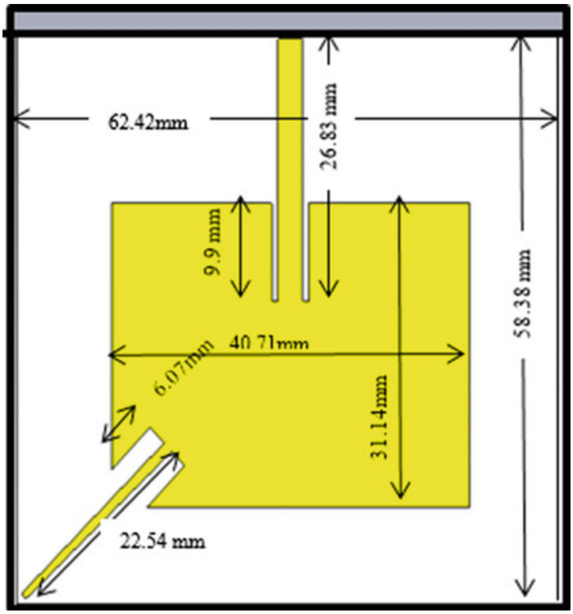

Fig. 1 Model of the proposed antenna

5 Design Analysis

5.1 *For Inset Feed*

The current is low (≈zero) at the extremes of the half-wave patch and increases progressing toward the center. The impedance $Z = V/I$ could be reduced for better impedance matching if the patch was fed closer to the center. Hence, the feed is inserted at a distance R from the end. The current has a sinusoidal distribution moving a distance R from the end, and therefore, it increases by a factor $\cos(\pi R/L)$. The input impedance of the feed can then be evaluated as

$$Z_{\text{in}}(R) = \cos(\pi R/L) \cdot Z_{\text{in}}(0) \tag{8}$$

where $Z_{\text{in}}(0)$ is input impedance if patch was fed at the boundary.

Generally, the distance R is taken to be $R = L/4$. Plugging the value of R, Eq. 8 becomes

$$Z_{\text{in}}(R) = \left(\frac{1}{\sqrt{2}}\right)^2 Z_{\text{in}}(0) \tag{9}$$

The insertion of the feed by an amount of 1/8 of the wavelength would decrease input impedance by 50%.

5.2 *For Diagonal Feed*

When the rectangular patch is fed along the diagonal, modes TM10 and TM01 get energized, which are equal in magnitude and orthogonal in phase. These two modes add together and produce circular polarization along the diagonal of the designed patch antenna. Thus, the ratio of w/L may be adjusted to detune each mode slightly so that each mode is equal at a single resonant frequency. This enhances the bandwidth by providing better broadside radiation pattern at the resonating frequency and also improves the antenna gain, also reducing the VSWR and return loss.

6 Analysis of Results

The reflection coefficient at Port1 (**S11**), Fig. 2, was achieved as **−19.233 dB at 2248 MHz** and **−20.314 dB at 1564 Mhz** on Port2 (**S22**), Fig. 3.

This indicates that the maximum energy transfer from the source to the antenna ports has taken place at the two resonant frequencies, respectively. It can also be seen that Port1 has a bandwidth of 70 MHz and Port2 has a bandwidth of 20 MHz. The

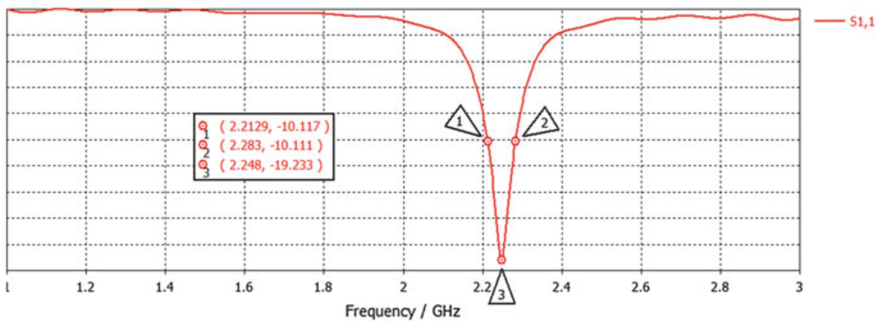

Fig. 2 S11 at Port1

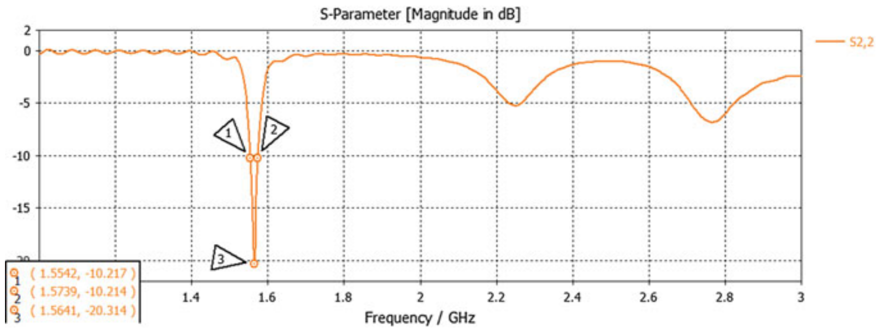

Fig. 3 S22 at Port2

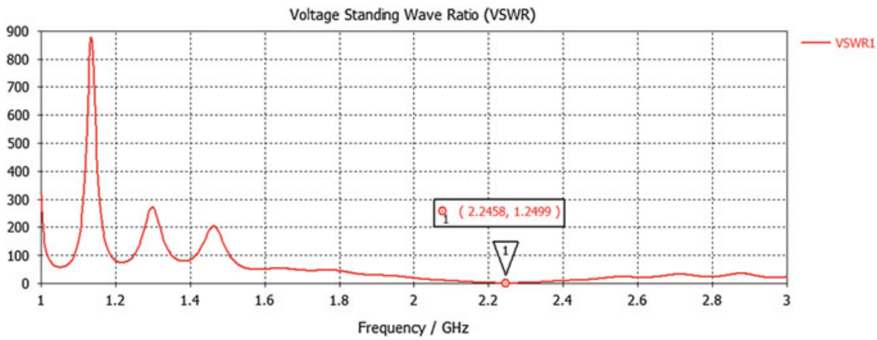

Fig. 4 VSWR at Port1

voltage standing-wave ratio (**VSWR**), Fig. 4, was achieved as **1.24 for 2.245 Ghz at Port1**(VSWR1) and **1.24 for 1.564 Ghz at Port2** (VSWR2), Fig. 5. These values indicate that the impedance values of the two ports of the antenna are well matched with the transmission line.

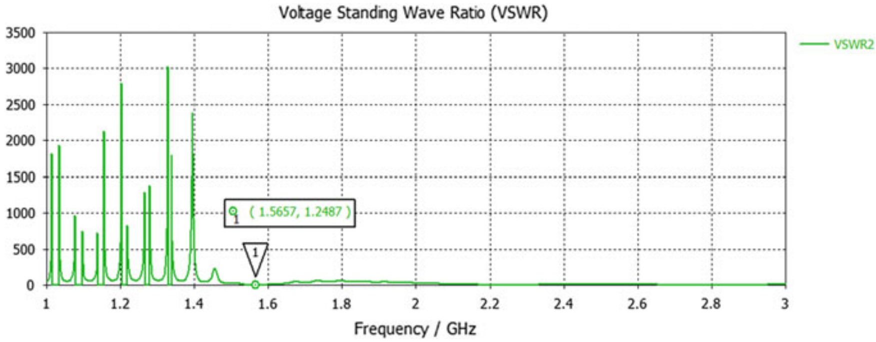

Fig. 5 VSWR at Port2

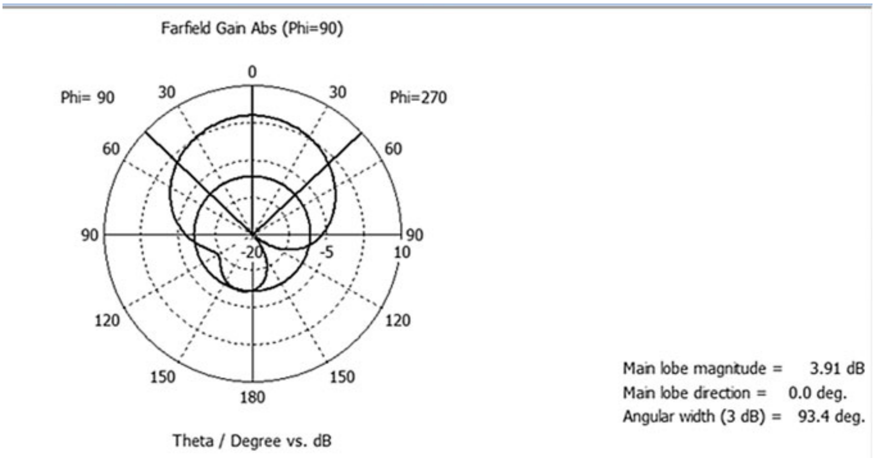

Fig. 6 Radiation pattern Port1

Table 2 Comparison of results

Simulated result		Manufactured result					
Return loss		VSWR		Return loss		VSWR	
Port1	Port2	Port1	Port2	Port1	Port2	Port1	Port2
−19.233 dB	−20.314 dB	1.24	1.24	−20.14 dB	−13.631 dB	1.3	1.24

The radiation pattern, Fig. 6, attained shows a gain of 3.91 dB at Port1 and 3.59 dB at Port2, Fig. 7. The above designed antenna was fabricated in the local market, Fig. 8. On subjecting the fabricated dual-port microstrip patch antenna to tests on the VNA, the reflection coefficient was achieved as **−13.631 dB at 1.58 GHz,** Fig. 9, as compared to **−20.31 dB at 1.58 GHz** achieved in the CST software simulation, as reflected in Table 2.

This reflects a drop in the performance of Port2. This is attributed to the dimensions of the fabricated antenna not matching with the designed dimensions. The thickness

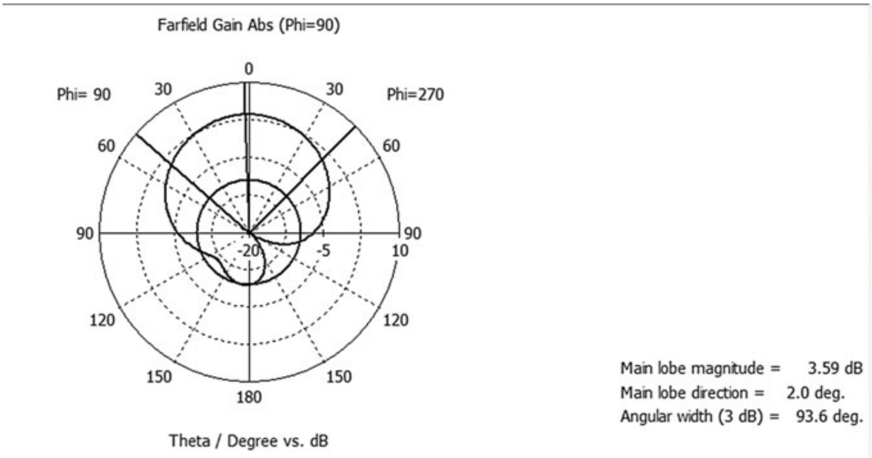

Fig. 7 Radiation pattern Port2

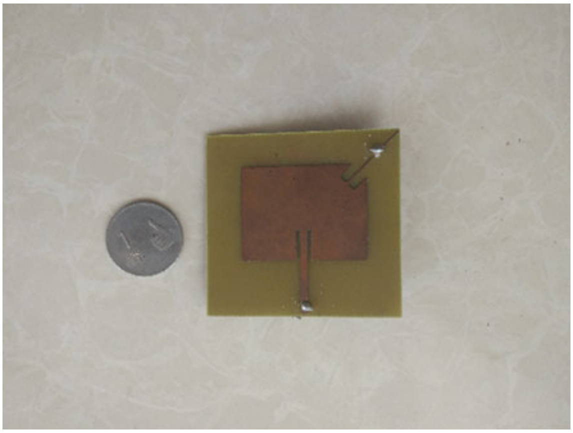

Fig. 8 Fabricated patch antenna

of the substrate was observed to be varying by 1.2 mm. Hence, a drop in the reflection coefficient value at Port2 due to dimension mismatch. The voltage standing-wave ratio was achieved as **1.3 at 2.2 GHz,** Fig. 10, as compared to **1.24 at 2.2 Ghz** achieved in the software results. This shows the accuracy and the correctness of the design, and it also confirmed the simulated software results.

7 Conclusion

The design of a dual-port microstrip patch antenna for wireless applications has been proposed. It is observed that the proposed antenna effectively resonates at

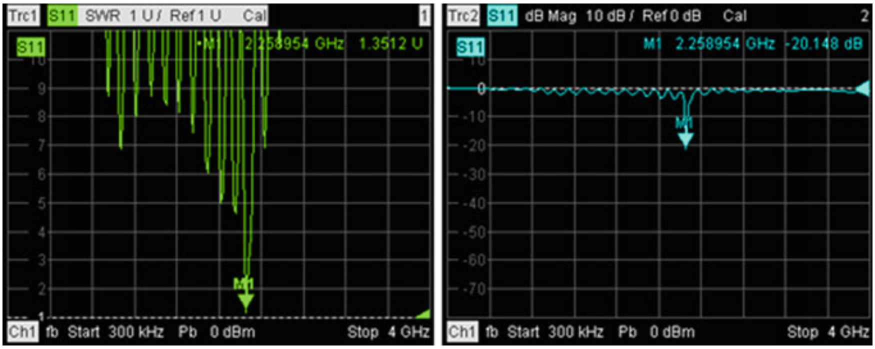

Fig. 9 Measured S11 of patch antenna

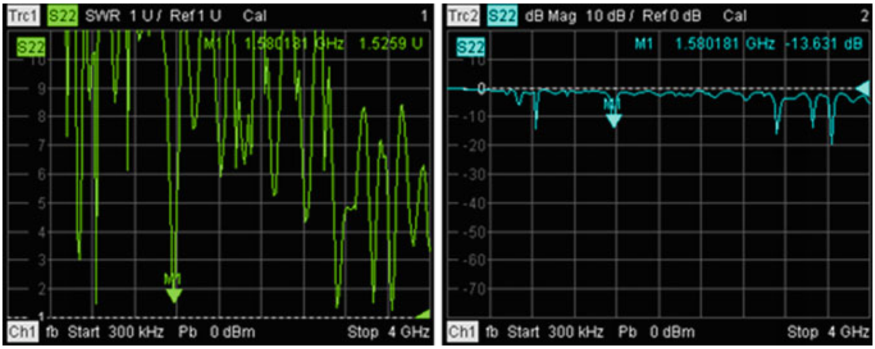

Fig. 10 Measured VSWR of patch antenna

two frequencies 2.2 Ghz (telemetry) and 1.5 Ghz (GPS). The location of the patch and the feed lines have been optimized in such a way that the antenna can operate in two frequencies at same time. Values of all the parameters, namely the return loss, radiation pattern, VSWR, and gain obtained, are considered to be good and acceptable values. The designed antenna parameters can be utilized for a conformal configuration that would make it suitable for onboard telemetry applications.

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